EXTRATERRESTRIAL HELIUM IN URBAN DUST AND IN A SINGLE URBAN SPHERULE – THE END OF THE URBAN MYTH?

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Introduction: Micrometeorites (MMs) are sub-millimeter sized extraterrestrial (ET) dust particles, shed from comets and asteroids [1]. Micrometeorites (and interplanetary dust particles < 20 um) are the largest source of ET material delivered to Earth, at a rate of about 30,000 tons per year [2]. Collecting MMs is presently considered a 'tricky business' [3], as they are easily lost amongst terrestrial and anthropogenic particles. Therefore, the majority of MMs in scientific collections, have been recovered from clean environments (limited anthropogenic contamination) with low terrestrial sedimentation rates, such as Antarctic snow [4, 5] and deep sea sediments [6]. Recently however, [7, 8] presented evidence for an ET origin of 48 *urban* MMs (>300 µm; based on CI-chondritic compositions within a factor of three), challenging the current assumption that, collecting MMs from densely populated areas is an '*urban myth'* [7, 8]. In this preliminary study, we collected urban dust from an external window sill, separated the magnetic fraction, and selected 12 MM candidates (MMCs) from this magnetic separate. Each of the 12 MMCs, and the remaining magnetic separate were measured for He and Ne, to see if we could find an ET signature, thus confirming the findings of [7, 8].

Methods: Samples were collected in September 2016 from a dust-filled crevice between the external window sill and ledge of a building of the Department of Earth Science at ETH Zurich (room NW D75.1). The magnetic separate of this dust had a total mass of ~ 30 mg. A 2.7 mg aliquot of this magnetic separate (MS-1) was studied using a binocular microscope. Black-metallic spherules (~20 to 200 µm) make up about 60% of MS-1. Fifty of these spherules were picked from MS-1. MS-1 was then measured for light noble gases (^{3}He, ^{4}He, ^{20}Ne, ^{21}Ne and ^{22}Ne) using a custom-built noble gas mass spectrometer at ETH Zurich. Chemical compositions of the 50 spherules were determined using a scanning electron microscopy with energy dispersive system (SEM-EDS). The results showed that ~40 spherules had external textures and compositions consistent with those reported for iron MMs [9]. Eleven of the largest (~80-200 µm) and one of the smallest (~25 µm) spherules were selected as MMCs. They were placed into individual pits in an Al-mount and loaded into the sample chamber of a compressor source mass spectrometer, connected to an ultra-low blank extraction line [10]. Each MM was heated individually for 1 minute with a Nd:YAG laser (λ = 1064 nm) until complete vaporization. Samples were then analyzed for He and Ne based on protocol developed by [11].

To estimate the mass of MMCs, each was approximated to a sphere and mass errors determined from repeat measurements of grain diameters. The density was assumed to be 5.2 g/cm^{3}, an average

Samples	**SEM-EDS FeO (%)**	**Diameter (µm)**	**Mass (µg)**	**^{3}He/^{4}He (x10^{-4})**	**^{4}He/^{20}Ne**	**^{20}Ne/^{22}Ne**	**^{21}Ne/^{22}Ne**	**^{3}He (x10^{-15}) (x10^{-15}cm^{3}STP)**	**^{4}He (x10^{-12}cm^{3}STP)**	**^{22}Ne (x10^{-15}cm^{3}STP)**
MMC _1	100	197	21.0		< 9.1	7.2 ±4.3	< 0.012			9.4 ±5.5
MMC _2	**98.3**	**160**	**11.2**	**3.7 ±0.7**	**> 69.2**	**< 7.34**	**0.03 ±0.04**	**1.3 ±0.2**	**3.5 ±0.1**	**6.8 ±3.9**
MMC _3	97.2	187	17.9	< 0.9	1.2 ±0.1	9.87 ±0.12	0.03 ±0.002		4.4 ±0.4	364 ±4.1
MMC _4	99.0	123	5.12				> 0.04			
MMC _5	98.8	117	4.44		< 12.3	> 8.34	> 0.03			
MMC _6	96.8	87.9	1.86				> 0.02			
MMC _7	(Ti,Fe,Si)	80.5	1.43							
MMC _8	97.1	125	5.32			< 4.68	0.03 ±0.03			0.2 ±8.0
MMC _9	98.5	108	3.42				> 0.05			
MMC _10	**100**	**25**	**0.04**	**0.7 ±0.3**	**1.3 ±0.1**	**9.6 ±0.2**	**0.03 ±0.001**	**0.6 ±0.3**	**7.9 ±0.8**	**644 ±7.3**
MMC _11	99.0	97.8	2.57	< 3.0	> 26.0	< 5.16	< 0.01		1.3 ±0.5	9.7 ±7.6
MMC _12	100	131	6.13							
MS-1	-	-	**2.7 (mg)**	**8.2 ±1.1**	**50.5 ±7.0**	**13.1 ±0.1**	**0.03 ±0.001**	**28430 ±160**	**3450 ±477**	**52395 ±192**
Earth's Atm				0.014	0.32	9.8	0.0290			
fSW				2.17	400	11.2	0.0295			
SW				4.57	656	13.78	0.0329			

Table. 1. All samples measured in this study and their noble gas characteristics. MS-1 refers to the 2.7 mg aliquot of the magnetic separate, and micrometeorite candidate (MMC) samples are numbered accordingly. Less than and greater than symbols show upper and lower limits for partially detectable ratios, respectively. Noble gas compositions given for Earth's atmosphere (Earth's Atm), fractionated solar wind (fSW), and solar wind (SW) are from [12].

density for common iron-oxide minerals typically found in iron MMs (e.g., FeO, $Fe_2 O_3$ and Fe_3O_4). Typical mass errors are c. 30%.

Results & Discussion: So far, 12 MMCs have been measured for light noble gases, ten of which (MMCs 1-6 and 8-11) have He and/or Ne above the respective detection limit (DL; Table 1). However, MMCs 1, 4, 5, 6, 8 and 9 are compatible (within very large uncertainties) with atmospheric He and Ne, thus are not discussed further. The He isotopic ratio (^{3}He/^{4}He) for the remaining MMCs (2, 3, 10, and 11) and MS-1 are shown in Fig. 1. Both MS-1 and MMC 2 have ^{3}He (and ^{4}He) above the DL and ^{3}He/^{4}He compatible with solar wind (SW; Table 1). They also yield ^{4}He/^{20}Ne clearly above Earth's atmosphere (air), further supporting a SW origin. The upper limit on the ^{3}He/^{4}He of MMC 11, and the high ^{4}He/^{20}Ne (>26), are also compatible with SW. However, without ^{3}He above DL, a radiogenic origin for the ^{4}He cannot be excluded. The upper limits on ^{3}He/^{4}He for MMC 10 and 3 fall between fractionated solar wind (fSW) and air, and their ^{4}He/^{20}Ne are above the atmospheric value (Table 1; Fig. 1). Still, with no measurable ^{3}He above the DL for these MMCs, their ET origin cannot be concluded. The Ne isotopic compositions of MS-1 and all MMCs, which had at least one Ne isotope above the DL, are shown in Fig. 2. The Ne in MS-1 can be attributed to a mix of SW, fSW and cosmogenic Ne. The MMCs have low ^{21}Ne/^{22}Ne and ^{20}Ne/^{22}Ne compared to ratios reported for Antarctic and deep sea MMs [4-6], which typically fall between air and SW (^{20}Ne/^{22}Ne = 10–15; ^{21}Ne/^{22}Ne = 0.025–0.056). However, the Ne released from the MMCs is likely dominated by atmospheric Ne, because the SW ^{20}Ne expected from the measured SW ^{4}He is below the detection limit. The SW gases of MS-1 display much higher concentrations than those measured in MMC 2 (Table 1; Fig. 1-2). This indicates that there must be an additional carrier of SW gases within urban dust that we have yet to identify and analyze. From estimates of the annual cosmic spherule flux to Earth (20 – 200 µm; [13]), we would expect 4 MMs (similar to MMC 2; ~10 µg) to be deposited on the window ledge (~ 4000 cm^{2}), since completion of the building in 1916 [14]. From the collected window sill dust (30 mg; magnetic separate), only 10% (MS-1) has been searched, and one MM already recovered, suggesting higher accumulation rates than expected.

Conclusions: We report the *first* discovery of extraterrestrial He and Ne (SW) in < 3 mg magnetic separate of urban dust (Zurich, Switzerland). Additionally, from the 12 spherules (20 – 200 µm) selected from that separate, we have detected one (MMC 2) with a SW He isotopic composition, confirming its ET origin. Our single MM cannot explain the very high concentrations of SW gases in the magnetic separate, suggesting the presence of other noble gas carriers. This discovery supports the conclusions of [7, 8], that MMs can indeed be collected from urban environments, and thus may not be an *urban myth,* as commonly assumed.

References: [1]Brownlee D. E. (2016) *Elements, 12,* 165–70. [2]Love S. G. and Brownlee D. E. (1993) *Science, 262,* 550–53. [3] Taylor S. et al. (2016) *Elements*, 12, 171. [4] Bajo K-I. et al. (2011) *EP&S*, 63, 1097-*1*111. [5] Osawa T. et al. (2010) *M&PS,* 45, 1320-1339. [6] Osawa T. (2012) DOI: 10.5772/35365. [7] Larsen J. and Genge, M. J. (2016) *M&PSA 51* #6341. [8] Genge, M. J. et al. (2016) *Geology*, 45, G38352.1. [9] Genge, M. J. (2008) *M&PS.,* 43, 497-515, [10] [Baur H. (1999) EOS Trans., AGU 46, #F1118. [11] [Heck P. R. et al. (2007) *APJ* 656, 1208-1222. [12] Ott U. (2014) *ChE* 74, 519-544. [13] Love S. and Brownlee D. (1991) *Icarus* 89, 26-43. [14] http://bit.ly/2iXXtFL (Acc. 09.12.2016)

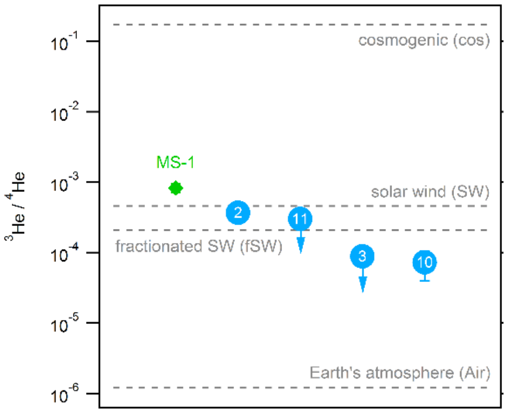

Fig. 1. Measured ^{3}He/^{4}He for the magnetic separate (MS-1; green) and selected micrometeorite candidates (MMCs; blue). Reference fields for He compositions (grey) are from [12]

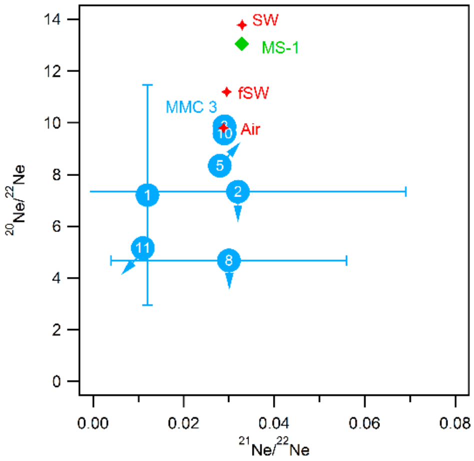

Fig. 2. Three isotope diagram of Ne for magnetic separate (MS-1; green) and micrometeorite candidates (MMCs; blue). Reference values (red) are from [12]